

Charge of a particle generated by a captured pair of photons

Herbert Weiß*

Am Bucklberg 19, D-83620 Feldkirchen-Westerham, Germany

(Dated: February 2, 2008)

The model of charge generation is based on the wave model of a particle, for which a brief description is given. The particle is comprised of two photons, captured in the volume of the particle, and reveals the complete relativistic behaviour. The electromagnetic waves of the two photons are supposed to induce an electrostatic field. The surface integral of this electrostatic field is identified with the charge of the particle. The magnitude of the electric field is derived from the energy density of the photons. The volume and the surface are related to the wavelength of the photons, thus leading to a charge of the particle, which is independent of its mass.

PACS numbers: 21.10.Ft, 03.75.-b, 03.30.+p

Keywords: Charge of a particle; Wave model of a particle

I. INTRODUCTION

In classical mechanics, as well as in quantum mechanics, the positive or negative charge of a particle is postulated to be an integer multiple of elementary charge e , with a numerical value of $1.602\,176\,53 \times 10^{-19}$ Coulomb (As) in SI units. Charge is a physical quantity with outstanding properties: In nature, it can achieve only two values, $+e$ and $-e$. The charge of a particle is independent from its mass. Charge remains constant under any coordinate transformation, the law of charge conservation is independent of the metric used, it is a premetric law [1]. – Nevertheless, there is only very few knowledge about the nature of charge.

Naudts and Kuna [2] give a new formulation of the particle model from Doplicher, Fredenhagen, and Roberts, yielding the expression $b^2 = \lambda \hbar c_0 / (2\pi)$ for the charge b of the proton. λ is arbitrarily chosen and is assumed to be the fine structure constant α . – Chernitskii [3] takes the idea of dyons from Schwinger. Dyons are entities which carry electric charge as well as magnetic charge. He creates bidyons in taking two dyons a distance $2a$ apart with equally sized electric charges d of same polarity and equally sized magnetic charges b of opposite polarity in order to cancel the net magnetic flux of a closed surface covering the particle. Dyons are supposed to have either electric charge and/or magnetic charge. – Azcàrraga et. al. [4] report from a relativistic particle model using a pair of twistors in a Liouville one-form which leads to an enhanced phase space of 18 dimensions. Quantization provides a set of wave equations determining mass, spin and electric charge of a relativistic particle. The sum of internal scalar charge t_0 and t_3 equals the electric charge e_p of the particle. Subsequently, constraint R_6 equates e_p with elementary charge e . – Fedoruk et. al. [5] extend the Shirafuji model using a two-twistor description and quantize the model in order to obtain wavefunctions de-

scribing relativistic particles with mass, spin, and electric charge. They predict numerical values coming from the solution of suitable chosen constraints. The symbol q enters constraint 4.2d for the charge of the particle, and q is identified with elementary charge e . – A merely speculative attempt to give an explanation of charge, independent from e , comes from Baten [6], who suggests to relate electric charge $+e$ and $-e$ to possible squeeze phases $+1$ or -1 of a hypothetical electromagnetic protofield movement towards the so-called reduction center of a particle. – Another approach is that of Hadley [7], who states that Stokes theorem has limited application in manifolds that are not time orientable. He says: “when the theorems do not apply, it is possible to have the appearance of charge arising from the source free equations, because there can be a net surface flux with zero enclosed charge.” The non-zero net flux can give rise to either a virtual electric charge as well as a magnetic charge. – One can imagine the difficulties and the enormous effort arising from the theoretical framework necessary to provide a solid basis for a theory violating Stokes’ or Gaussian theorem in order to yield an expression for the electric charge of a particle. We mention this, because our approach positively applies Gaussian theorem in the usual manner, and it is quite sufficient to yield a mechanism for creating charge without endeavoring a special particle carrying elementary charge e , as will be shown below.

The models of charge, given in [2, 3, 4, 5], have reference to elementary charge e , meaning that the models are adjusted to comply with observations. The charge model presented here suffers from the same problem, it requires the constant C_W . Future development of the model is supposed to resolve constant C_W .

The mechanism of charge generation is based on the wave model of a particle given in [8]. In order to provide a sufficient basis for the charge model, we give a brief description of the wave model in section II. The actual model of charge generation is presented in section III. – All equations are given exclusively in SI units.

*Email: hw@terminal-e.de

II. WAVE MODEL OF A PARTICLE

Since Max Planck postulated in 1900 the electromagnetic radiation being emitted and absorbed by discrete quanta [9] and the correct interpretation of the photo effect in 1905 by Albert Einstein [10], the dual nature of electromagnetic waves was evident. Photons possess properties of waves according to Maxwell equations as well as properties of particles with momentum p according to Eq. (1),

$$p = \frac{h}{\lambda}, \quad (1)$$

with h the Planck's constant and λ the wavelength of the photon. De Broglie's idea was to assume a similar duality for particles [11]. He related the momentum p of a particle with mass m and speed v , Eq. (2), to a matter wave of wavelength λ , Eq. (3).

$$p = mv \quad (2)$$

$$\lambda = \frac{h}{mv} \quad (3)$$

Four years later, in 1927, Davisson and Germer [12] experimentally confirmed de Broglie's postulate by a diffraction experiment with an electron beam directed on Ni-crystals. The year before Erwin Schrödinger used the idea of matter waves and defined a wave equation for particles, the Schrödinger equation [13]. The solution of this wave equation gave the first reasonable explanation for the discrete states of an electron in an atom and was the start of quantum mechanics. The dual properties of particles are commonly accepted. The wave properties are derived from equality (1), which is originally valid for light quanta. For this reason the conjecture is near at hand that a particle *consists* of light quanta. This idea was used in the wave model of a particle.

A. Definition of wave model

A particle P is assumed to consist of two light quanta Q_h and Q_r traveling in opposite directions (Fig. 1).

$$P = \{Q_h, Q_r\} \quad (4)$$

For convenience we assume these directions being aligned with the x -axis. The light quanta are captured between two walls L and R . We do not specify the nature of the walls, we treat them being able to reflect the electromagnetic wave of the captured photons, regardless of the energy. Quantum Q_h travels in the positive x -direction, is reflected by the right-hand wall R , and the reflected part contributes to quantum Q_r . Quantum Q_r travels in the negative x -direction, is reflected by the left-hand wall L , and the reflected part contributes to quantum Q_h . The two walls must be held at a certain

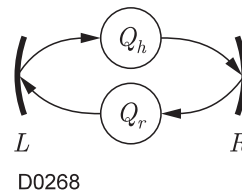


FIG. 1: Wave model of a particle with quanta Q_h and Q_r . The wave of Q_h is reflected at the right-hand wall R and the reflected part contributes to quantum Q_r . The wave of Q_r is reflected at the left-hand wall L and the reflected part contributes to quantum Q_h .

distance d_x in order to enable constructive interference of the two waves.

Tables I and II list the quantities pertaining to the model. All vectorial quantities are represented by their x -component with the corresponding basis vector \hat{x} being omitted, the y - and z -components are assumed to be zero unless otherwise noticed.

TABLE I: Quantities assigned to the particle P

symbol	description
Q_h	quantum traveling in the positive x -direction
Q_r	quantum traveling in the negative x -direction
R	right-hand wall
L	left-hand wall
v	drift velocity in the positive x -direction
W_g	energy of the particle
p_g	momentum of the particle in positive x -direction
n_g	wave count of the particle
λ_d	de-Broglie wavelength of the particle
d_x	dimension parallel to the x -axis
d_\perp	dimension perpendicular to the x -axis
s_g	propagation length of a complete cycle

TABLE II: Quantities assigned to quanta Q_h and Q_r

symbol	description
f_h	frequency of Q_h
λ_h	wavelength of Q_h
n_h	wave count of Q_h
W_h	energy of Q_h
p_h	momentum of Q_h
s_h	propagation length of Q_h
f_r	frequency of Q_r
λ_r	wavelength of Q_r
n_r	wave count of Q_r
W_r	energy of Q_r
p_r	momentum of Q_r
s_r	propagation length of Q_r

The energy W_g of the particle is simply the sum of energies W_h and W_r of the two light quanta

$$W_g = W_h + W_r, \quad (5)$$

and the energies W_h and W_r are given by formulae

$$W_h = hf_h \quad (6)$$

$$\text{and } W_r = hf_r, \quad (7)$$

with h denoting Planck's constant. Putting Eqs. (6) and (7) into Eq. (5) yields Eq. (8) defining the energy E_g of the particle in terms of the frequencies f_h and f_r .

$$W_g = h(f_h + f_r) \quad (8)$$

The momentum p_g of the particle is the sum of momenta p_h and p_r

$$p_g = p_h + p_r, \quad (9)$$

with p_h and p_r given by formula (10) and (11).

$$p_h = \frac{h}{c_0} f_h \quad (10)$$

$$p_r = -\frac{h}{c_0} f_r \quad (11)$$

Momentum p_r must be less than zero, because Q_r is traveling in the negative x -direction. Again, putting Eqs. (10) and (11) into Eq. (9) yields Eq. (12) defining the momentum p_g of the particle in terms of the frequencies f_h and f_r .

$$p_g = \frac{h}{c_0} (f_h - f_r) \quad (12)$$

The wavelengths λ_h and λ_r of the particle are simply:

$$\lambda_h = \frac{c_0}{f_h} \quad (13)$$

$$\text{and } \lambda_r = \frac{c_0}{f_r}. \quad (14)$$

In order to obtain constructive interference, the sum n_g of wavecounts n_h and n_r must be an integer,

$$n_g = n_h + n_r, \quad (15)$$

with conditions (16) and (17).

$$n_h, n_r \in \mathbb{R} \quad (16)$$

$$n_g \in \mathbb{N} \quad (17)$$

Length d_x of the particle in the x -direction equals the product of wave count n_h and wavelength λ_h , as well as the product of wave count n_r and wavelength λ_r .

$$d_x = n_h \lambda_h = n_r \lambda_r \quad (18)$$

From Eq. (18) we get a relation between wave counts and wavelengths.

$$\frac{n_h}{n_r} = \frac{\lambda_r}{\lambda_h} \quad (19)$$

Using Eqs. (13) and (14) Eq. (19) acquires the form (20):

$$\frac{n_h}{n_r} = \frac{f_h}{f_r} \quad (20)$$

The propagation length s_g is the sum of distances s_h and s_r a state of the electromagnetic wave propagates, starting at the left-hand wall L , traveling to the right-hand wall R , and traveling back to the left-hand wall L after reflection at the right-hand wall R . Distances s_h and s_r are measured in the frame at rest, even for the moving particle.

$$s_g = s_h + s_r \quad (21)$$

We define the intrinsic period T of the particle, measured in the system at rest, as the time elapsed required for a state of the electromagnetic wave to travel the distance s_g .

$$T = \frac{s_g}{c_0} \quad (22)$$

B. Particle at rest

At rest, the frequencies f_h and f_r of both quanta Q_h and Q_r are equally and have magnitude f_0 .

$$v = 0 \quad \Rightarrow \quad f_h(0) = f_r(0) = f_0 \quad (23)$$

From Eqs. (8) and (12) we obtain the energy $W_g(0)$ and the momentum $p_g(0)$ of the particle at rest.

$$W_g(0) = hf_0 \quad (24)$$

$$p_g(0) = \frac{h}{c_0} (f_0 - f_0) \equiv 0 \quad (25)$$

From Eqs. (23), (13), and (14) we get wavelengths $\lambda_h(0)$ and $\lambda_r(0)$ by Eq. (26).

$$\lambda_h(0) = \lambda_r(0) = \lambda_0 = \frac{c_0}{f_0} \quad (26)$$

The quanta at rest have equally wave lengths and hence equally wave counts due to Eq. (19).

$$n_h(0) = n_r(0) = n_0 = \frac{n_g}{2} \quad (27)$$

Length $d_x(0)$ of the particle at rest is given by formula (28).

$$d_x(0) = n_0 \lambda_0 = \frac{n_g c_0}{2 f_0} \quad (28)$$

In the frame at rest, isotropy of speed of light is assumed. Regarding the propagation of an electromagnetic wave in directions different from x , the particle at rest must have the shape of a sphere in order to maintain constructive interference in these directions. Thus, the

diameter of the particle in any direction equals $d_x(0)$, which we denote as d_0 .

$$d_0 = \frac{n_g c_0}{2f_0} \quad (29)$$

Then, the surface of a particle resting in the origin of the coordinate sytem is given by Eq. (30),

$$x^2 + y^2 + z^2 = \frac{d_0^2}{4}, \quad (30)$$

and the diameters d_y and d_z , perpendicular to direction x , are given by Eq. (31).

$$d_y(0) = d_z(0) = d_\perp = d_0 \quad (31)$$

Distances s_h and s_r are equally and are the same as length d_0 , so that the sum s_g is given by Eq. (32)

$$s_g = 2d_0 = \frac{n_g c_0}{f_0} \quad (32)$$

The intrinsic time period T_0 of the particle at rest is given by Eq. (33).

$$T_0 = \frac{s_g}{c_0} = \frac{n_g}{f_0} \quad (33)$$

C. Particle moving at velocity v

Now, the particle moves at velocity v in the positive x -direction. That means, the two walls are moving at speed v . The frequencies of quanta Q_h and Q_r must be different because of the Doppler effect. Considering the reflection of the wave at the right-hand wall R yields relation (34) of frequency f_h to frequency f_r .

$$\frac{f_h}{f_r} = \frac{c_0 + v}{c_0 - v} \quad (34)$$

Here, we encounter the problem that the relation to the particle at rest is lost. The identity of the particle at rest is the frequency f_0 . In order to recover the relation, we introduce condition (35): the geometrical mean of frequencies f_h and f_r must be equal to the frequency f_0 .

$$\boxed{\sqrt{f_h f_r} = f_0} \quad (35)$$

With Eq. (35) the frequencies f_h and f_r of the moving particle can be calculated from Eq. (34) and yields

$$f_h = f_0 \sqrt{\frac{c_0 + v}{c_0 - v}} \quad (36)$$

$$\text{and} \quad f_r = f_0 \sqrt{\frac{c_0 - v}{c_0 + v}}. \quad (37)$$

Using formula (38) and (39) for the sum and the difference of frequencies f_h and f_r ,

$$f_s = f_h + f_r = \gamma 2f_0, \quad (38)$$

$$\text{and} \quad f_d = f_h - f_r = \gamma 2f_0 \frac{v}{c_0}, \quad (39)$$

we obtain energy W_g and momentum p_g of the moving particle from Eqs. (8) and (12),

$$W_g = \gamma 2hf_0, \quad (40)$$

$$p_g = \gamma \frac{2hf_0 v}{c_0^2}, \quad (41)$$

with the gamma factor given by (42).

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c_0^2}}} \quad (42)$$

Using Eqs. (15) and (20) the wave counts n_h and n_r can be calculated from Eqs. (36) and (37).

$$n_h = \frac{n_g}{2} \left(1 + \frac{v}{c_0}\right) \quad (43)$$

$$n_r = \frac{n_g}{2} \left(1 - \frac{v}{c_0}\right) \quad (44)$$

The length d_x of the moving particle is from Eqs. (13), (18), (36), and (43)

$$d_x = d_0 \sqrt{1 - \frac{v^2}{c_0^2}}. \quad (45)$$

The propagation length s_g of the moving particle is given by Eq. (46).

$$s_g = \gamma \frac{n_g c_0}{f_0} \quad (46)$$

The intrinsic time period T of the moving particle is given by Eq. (47).

$$T = \gamma \frac{n_g}{f_0} \quad (47)$$

Considering the propagation of the electromagnetic wave in directions different from x and taking into account constructive interference, the moving particle must aquire the form of a rotational ellipsoid according to Eq. (48).

$$\gamma^2 x^2 + y^2 + z^2 = \frac{d_0^2}{4}, \quad (48)$$

D. Properties of the wave model

The wave model of a particle is derived from postulate (4) and condition (35) and yields the complete relativistic behaviour of matter:

- LENGTH CONTRACTION is demonstrated by Eqs. (30) and (48)
- TIME DILATION is demonstrated by Eqs. (33) and (47)

- RELATIVISTIC ENERGY is demonstrated by Eqs. (24) and (40)
- RELATIVISTIC MOMENTUM is demonstrated by Eqs. (25) and (41)

Moreover, the wave model is able to give an explanation for the enhanced lifetime of moving particles. The model predicts a particle to possess an internal clock, which is comprised of the captured photons bouncing between the two walls. The time elapsed between two ticks becomes longer the faster the particle moves.

E. de Broglie wavelength λ_d and phase speed c_φ

Equation (12) relates the momentum of the particle to the difference f_d of frequencies f_h and f_r .

$$f_d = f_h - f_r \quad (49)$$

Although the difference frequency f_d has no real representation, for instance, by a photon of energy hf_d captured within the walls, we can assign the wavelength λ_d according to Eq. (50).

$$\lambda_d = \frac{c_0}{f_d} \quad (50)$$

When we replace the difference frequency f_d with the right-hand side of Eq. (39)

$$\lambda_d = \frac{c_0}{\gamma 2f_0 \frac{v}{c_0}} \quad (51)$$

and enhance numerator and denominator with Planck's constant h , Eq. (51) acquires the form (52) after some simple rearrangement.

$$\lambda_d = \frac{h}{\frac{\gamma 2hf_0}{c_0^2} v} = \frac{h}{\frac{W_g}{c_0^2} v} \quad (52)$$

Using Einstein's energy mass equivalence formula, $W_g = m_g c_0^2$, we obtain finally Eq. (53)

$$\lambda_d = \frac{h}{m_g v}, \quad (53)$$

with m_g the correct relativistic mass of the moving particle. Equation (53) is identical with Eq. (3), meaning that the wave model of a particle yields an explanation for matter waves and for the de Broglie wavelength.

When the de Broglie wavelength is used to calculate the total energy of the particle employing Planck's formula $E = hf$, the corresponding frequency f_B must be calculated from a propagation speed other than speed of light. The correct frequency is obtained using a propagation speed of $c_\varphi = c_0^2/v$. This is called the *phase speed* in

order to avoid defining a propagation speed higher than speed of light.

$$f_B = \frac{c_\varphi}{\lambda_d} \quad (54)$$

$$c_\varphi = \frac{c_0^2}{v} \quad (55)$$

There is no mechanism known which is able to expound such an odd behaviour of this matter wave, especially the phenomenon that with velocity $v = 0$ the phase speed becomes infinity. Now, this problem can be solved with the wave model. At time t_0 we take a point on the x -axis where the phases φ_h and φ_r sum up to phase φ_s ,

$$\varphi_h + \varphi_r = \varphi_s, \quad (56)$$

and look for the condition of constant phase sum φ_s . The phases φ_h and φ_r of the wave functions for Q_h and Q_r , respectively, are given by Eqs. (57) and (58).

$$\varphi_h = 2\pi f_h \left(t - \frac{x}{c_0} \right) \quad (57)$$

$$\varphi_r = 2\pi f_r \left(t + \frac{x}{c_0} \right) \quad (58)$$

We substitute φ_h and φ_r in Eq. (56) with the right-hand side of Eqs. (57) and (58).

$$\begin{aligned} 2\pi f_h \left(t - \frac{x}{c_0} \right) + 2\pi f_r \left(t + \frac{x}{c_0} \right) &= \varphi_s \\ 2\pi (f_h + f_r) t - 2\pi (f_h - f_r) \frac{x}{c_0} &= \varphi_s \\ 2\pi f_s t - 2\pi f_d \frac{x}{c_0} &= \varphi_s \end{aligned} \quad (59)$$

Using Eqs. (38) and (39) for the sum f_s and the difference f_d of frequencies f_h and f_r , we obtain:

$$\begin{aligned} t - \frac{v}{c_0^2} x &= \frac{\varphi_s}{2\pi\gamma 2f_0} \\ x(\varphi_s, t) &= \frac{c_0^2}{v} t - \frac{c_0^2 \varphi_s}{v 2\pi\gamma 2f_0} \end{aligned} \quad (60)$$

This is the equation for the location $x(\varphi_s, t)$ as a function of constant sum φ_s of phases φ_h and φ_r and time t . The time derivative of x is the speed the state of constant phase φ_s propagates,

$$\frac{d}{dt} x(\varphi_s, t) = c_\varphi = \frac{c_0^2}{v}, \quad (61)$$

which is identified with the phase speed c_φ .

III. CHARGE OF THE PARTICLE

Maxwell equation of divergence (62) gives a relation between the electric field \mathbf{E}_q and the charge density ρ .

$$\nabla \cdot \mathbf{E}_q = \frac{\rho}{\varepsilon_0} \quad (62)$$

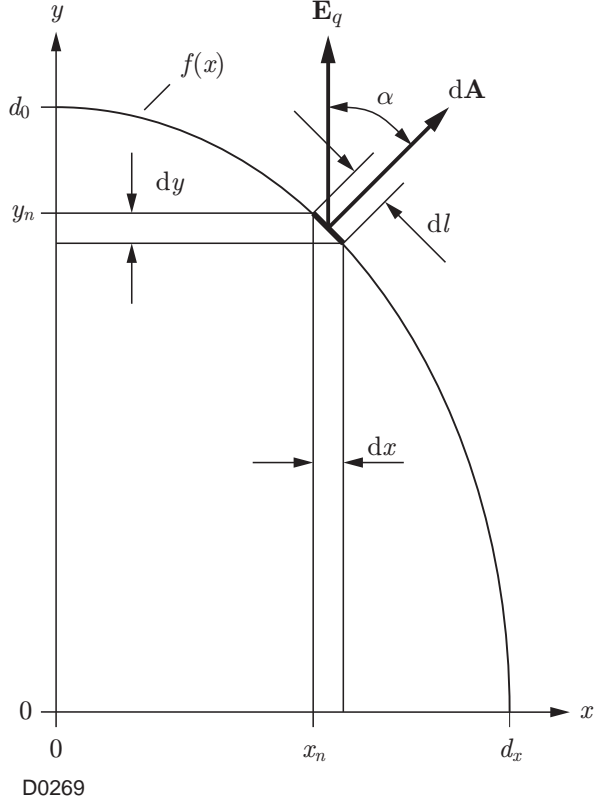


FIG. 2: Contour of the particle, cut in the x - y -plane. Location of vector \mathbf{E}_q relative to surface element $d\mathbf{A}$. The bold emphasized line element dl contributes to the surface element $d\mathbf{A}$. Line $f(x)$ is the outline of the particle.

We read this equation from the right-hand side to the left-hand side, i.e., we suppose the charge vector field \mathbf{E}_q makes the particle appear to possess charge q . Using Gaussian law the charge q is given by the surface integral of vector field \mathbf{E}_q over the surface A enclosing the particle.

$$q = \iint_A \varepsilon_0 \mathbf{E}_q d\mathbf{A} \quad (63)$$

$d\mathbf{A}$ is a vector of length dA pointing outside the surface of the particle.

A. Charge q in terms of E_w

We assume the field vector \mathbf{E}_q has a magnitude E_q proportional to the magnitude E_w of field vector \mathbf{E}_w at the surface of the particle. \mathbf{E}_w is the field vector of the electromagnetic wave pertaining to the photons Q_h and Q_r . Vector \mathbf{E}_q is common to the x - $d\mathbf{A}$ -plane but perpendicular to the x -axis, thus having angle α with vector $d\mathbf{A}$, Fig. 2.

$$\alpha = \angle (\mathbf{E}_q, d\mathbf{A}) \quad (64)$$

Constant C_E denotes the ratio of E_q and E_w .

$$E_q = C_E E_w \quad (65)$$

With the relations (63) and (65) charge q is given by

$$q = \iint_A \varepsilon_0 C_E E_w dA \cos \alpha \quad (66)$$

The particle has rotational symmetry with respect to the x -axis, thus the contour of the cross section is an ellipsis with diameter d_x in the x -direction and diameter d_0 perpendicular to x . The function $f(x)$ of the contour is

$$f(x) = \frac{d_0}{d_x} \sqrt{\frac{d_x^2}{4} - x^2} \quad (67)$$

Surface element dA equals the contour line element dl times $f(x)$ times angle $d\varphi$.

$$dA = dl f(x) d\varphi, \quad (68)$$

with the line element dl given by

$$(dl)^2 = (dx)^2 + [f'(x) dx]^2, \quad (69)$$

and $\cos \alpha$ the ratio of dx and dl .

$$\cos \alpha = \frac{dx}{dl} \quad (70)$$

We plug in Eqs. (67-70) into Eq. (66) and introduce the limits of the integrals, 0 and 2π for $d\varphi$, and $-d_x/2$ and $+d_x/2$ for dx .

$$q = \int_0^{2\pi} \int_{-d_x/2}^{+d_x/2} \varepsilon_0 C_E E_w dl \frac{d_0}{d_x} \sqrt{\frac{d_x^2}{4} - x^2} \frac{dx}{dl} d\varphi \quad (71)$$

The first integral over $d\varphi$ can be immediately executed and yields 2π , line element dl is cancelled, and the remaining integral,

$$q = 2\pi \varepsilon_0 C_E E_w \frac{d_0}{d_x} \int_{-d_x/2}^{+d_x/2} \sqrt{\frac{d_x^2}{4} - x^2} dx, \quad (72)$$

is solved using

$$\int_{x_1}^{x_2} \sqrt{a^2 - x^2} dx = \frac{1}{2} \left[x \sqrt{a^2 - x^2} + a^2 \arcsin \frac{x}{a} \right]_{x_1}^{x_2}.$$

$$q = \varepsilon_0 C_E E_w \frac{d_0}{2} \frac{d_x}{2} \pi^2 \quad (73)$$

B. Magnitude E_w in terms of energy W_g

In order to determine the magnitude of vector \mathbf{E}_w , we equate the energy W_w of an electromagnetic wave with the energy W_g of a particle.

$$W_w = W_g \quad (74)$$

The energy W_w is equal to the energy density w times the volume V occupied by the particle,

$$W_w = wV, \quad (75)$$

with the energy density w of an electromagnetic wave equal to the square of the electric field \mathbf{E}_w times electric constant ε_0 .

$$w = \varepsilon_0 \mathbf{E}_w^2 = \varepsilon_0 E_w^2 \quad (76)$$

Equations (76) and (75) plugged in into Eq. (74) yield

$$\varepsilon_0 E_w^2 V = W_g \quad (77)$$

The volume V of the particle, occupying an ellipsoid with diameters d_x and d_0 , is given by Eq. (78).

$$V = \frac{4}{3}\pi \frac{d_x}{2} \frac{d_0}{2} \frac{d_0}{2}$$

$$V = \frac{1}{6}\pi d_x d_0^2 \quad (78)$$

With Eq. (40) for the energy W_g of the particle, we obtain Eq. (79) for the magnitude E_w of the electric field of the photons.

$$\varepsilon_0 E_w^2 \frac{1}{6}\pi d_x d_0^2 = \gamma 2hf_0$$

$$E_w = 2\sqrt{\frac{3\gamma hf_0}{\varepsilon_0 \pi d_x d_0^2}} \quad (79)$$

C. Elimination of E_w , d_x , and d_0

Now, we can substitute E_w in Eq. (73) by the right-hand side of Eq. (79) and obtain

$$q = \varepsilon_0 C_E 2\sqrt{\frac{3\gamma hf_0}{\varepsilon_0 \pi d_x d_0^2}} \frac{d_0}{2} \frac{d_x}{2} \pi^2$$

$$q = \frac{C_E}{2} \sqrt{\varepsilon_0 3\gamma hf_0 d_x \pi^3}. \quad (80)$$

Substituting d_x by the right-hand side of Eq. (45) cancels the frequency f_0 , and we obtain expression (81) for the charge of the particle, *independent* of its energy.

$$q = \frac{C_E}{2} \sqrt{3 n_g \pi^3 \varepsilon_0 h c_0} \quad (81)$$

The dimensionless constant C_E gives the ratio of the mean value E_q of the charge vector field \mathbf{E}_q at the surface of the particle to the mean square E_w of the electric field \mathbf{E}_w derived from the energy of the particle. ε_0 , h , and c_0 are fundamental constants and the squareroot of their product has, indeed, the units of a charge, so we refer to the expression $\sqrt{\varepsilon_0 h c_0}$ as the “Planck charge” denoted by the symbol e_h , Eq. (82)

$$e_h = \sqrt{\varepsilon_0 h c_0}, \quad (82)$$

with a numerical value of $e_h = 1.326\,211\,23 \times 10^{-18}$ As. The remaining parameters can be summarized to the constant C_W given by

$$C_W = \frac{C_E}{2} \sqrt{3 n_g \pi^3}, \quad (83)$$

then Eq. (81) acquires the simple form (84).

$$q = C_W e_h \quad (84)$$

To adjust the wave model of charge to the elementary charge, we have to equate q with e and resolve Eq. (84) with respect to constant C_W . Because charges smaller than e never have been observed, we assume a wave count n_g of 1 for the electron, thus constant C_W is simply the ratio of e and e_h .

$$C_W = \frac{e}{e_h} = 0.120\,808\,547 \quad (85)$$

IV. CONCLUSIONS

We took the idea of captured photons from the wave model and calculated the electric field on the surface of a particle. The net flux of this electric field is equal to the charge of the particle, and our rather simple model showed that the charge is independent from its energy, i.e., independent from its mass, just like observed in nature. But we will not suppress the difficulties with this model.

Generally, the field vector \mathbf{E}_w of the electromagnetic wave oscillates at the frequency of the captured photons, and subsequently, the charge field vector \mathbf{E}_q should also oscillate. Then the mean of the field vector, sampled over a sufficient long time, should be zero, thus making the net flux to vanish and no charged particle should be observed. The captured photons must have a property rather different from free running electromagnetic waves. It seems like the captured photons being in a steady state, i.e., the time derivative of the electric field appears to be zero $\partial \mathbf{E}_P / \partial t = 0$. Another problem is that electrons, protons, and most of the other particles possess spin, but our model says nothing about the spin of a particle. The future development must solve these problems in order to achieve a model, where presently known properties of particles are adequately represented.

Regarding Eqs. (36) and (37) the wave model assumes a preferred frame of reference, and apparently it violates Lorentz invariance. Obviously, the transformation of coordinates applicable here must be different from Lorentz transformation, hence the Maxwell equations become changed and the objection must be taken serious that the wave model probably doesn't comply with some observable phenomena. Recently, it has been demonstrated [14, 15, 16] that a kind of a Galilean transformation, the

medium transformation, can be successfully applied on Maxwell equations and the results are compliant with observable phenomena. This medium transformation primarily applies on the wave model, leading to properties of space-time equal to those of Lorentz ether. But there is no discrepancy with relativity, because Lorentz transformation can also be applied on the wave model, it tolerates both transformations.

-
- [1] F. W. Hehl and Y. N. Obukhov, *Dimensions and units in electrodynamics*, physics/0407022v1 (2004).
 - [2] J. Naudts and M. Kuna, *Model of a quantum particle in spacetime*, hep-th/0012209 (2000).
 - [3] A. A. Chernitskii, *Bidyon as an electromagnetic model for charged particles with spin*, hep-th/0002083v1 (2003).
 - [4] J. A. de Azcàrraga, A. Frydryszak, J. Lukierski, and C. Miquel-Espanya, *Massive relativistic particle model with spin from free two-twistor dynamics and its quantization*, hep-th/0510161v2 (2006).
 - [5] S. Fedoruk, A. Frydryszak, J. Lukierski, and C. Miquel-Espanya, *Extension of the shirafuji model for massive particles with spin*, hep-th/0510266v1 (2005).
 - [6] B. J. Baten, *The particle model*, physics/0009085v1 (2000).
 - [7] M. J. Hadley, *Geometric models of a particle - the missing ingredient*, physics/0601032v1 (2006).
 - [8] H. Weiß, *Wellenmodell eines Teilchens* (H. Weiß, Unterhaching, 1991).
 - [9] M. Planck, *Annalen der Physik* **4**, 553 (1901).
 - [10] A. Einstein, *Annalen der Physik* **17**, 132 (1905).
 - [11] L. V. de Broglie, *Comptes Rendus* **177**, 507 (1923).
 - [12] C. J. Davisson and L. H. Germer, *Physical Review* **30**, 705 (1927).
 - [13] E. Schrödinger, *Annalen der Physik* **79**, 361 (1926).
 - [14] G. D. Puccini, *Found. Phys. Lett.* **16**, 475 (2003).
 - [15] B. Buonaura, *Found. Phys. Lett.* **17**, 627 (2004).
 - [16] H. Weiß, *Alternative to the principle of constant speed of light*, physics/0606242 (2006).